EMDF Comments Primarily Related to the Site Groundwater Characterization Fact Sheet
Due DOE June 7, 2022

Submitted to: OakRidgeEM@orem.doe.gov
Date Submitted: June 7, 2022

Subject: **Comments primarily related to the Site Groundwater Characterization fact sheet**

On November 4, 2021, several former TDEC employees sent a letter concerning the Environmental Management Disposal Facility (EMDF) to EPA Administrator Michael S. Regan. The December 29, 2021, response from Acting Assistant Administrator Barry N. Breen stated the EPA, DOE, and TDEC will solicit and consider public comments on new information before EPA and DOE finalize the ROD. This response letter encouraged us to review new information added to the Administrative Record file as well as provided to the public on a dedicated website. The website includes the following new information:

EMDF Site Groundwater Characterization fact sheet

EMDF Waste Acceptance Criteria fact sheet

EMDF Water Quality Protection for Bear Creek fact sheet

Draft Record of Decision – July 2021

Draft ROD Responsiveness Summary

Technical Memo #1: Phase 1 Field Sampling Results (July 2, 2018)

Technical Memo #2: Phase 1 Monitoring (May 23, 2019)

Development of Fish Tissue and Surface Water Preliminary Remediation Goals (April 28, 2022)

Performance Assessment for the Environmental Management Disposal Facility at the Y-12 National Security Complex, Oak Ridge, Tennessee (April 23, 2020)

Composite Analysis for the Environmental Management Waste Management Facility and the Environmental Management Disposal Facility, Oak Ridge, Tennessee (April 16, 2022)

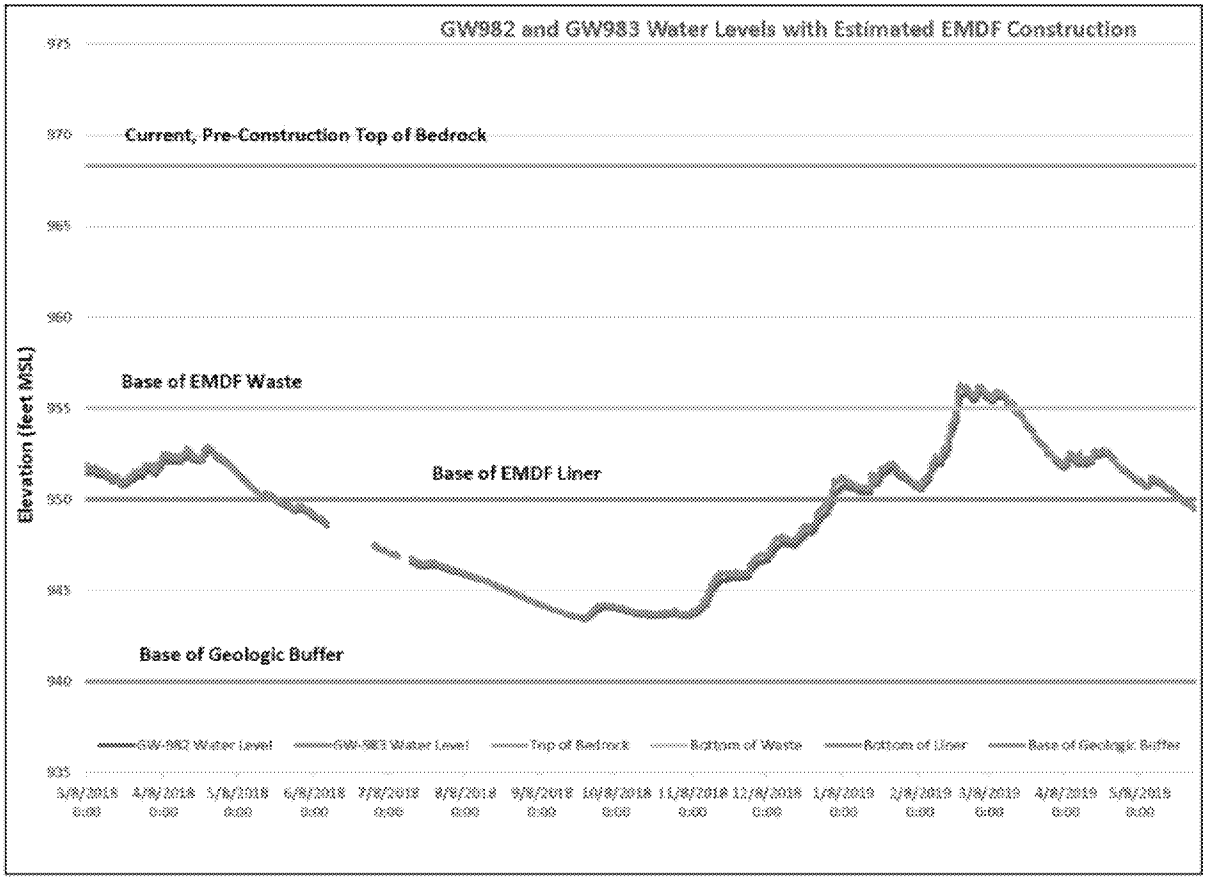
Link to the Oak Ridge Environmental Information System (OREIS)

1) The Site Groundwater Characterization fact sheet includes several important points to groundwater characterization including:
   a) There are fluctuations in groundwater elevations with seasons and rainfall.
   b) The highest groundwater elevations occur following large rain events and in the wet season.
   c) A short-term increase and decrease in groundwater elevation occur directly related to rainfall.
   d) Areas to be excavated for Cells 1 and 2 have existing groundwater elevations higher than elevations of the proposed multi-layer EMDF landfill base.
   e) A properly installed landfill liner system should prevent rain from percolating into the subsurface. (Except this may not be true adjacent to the outside limits of the landfill liner.)

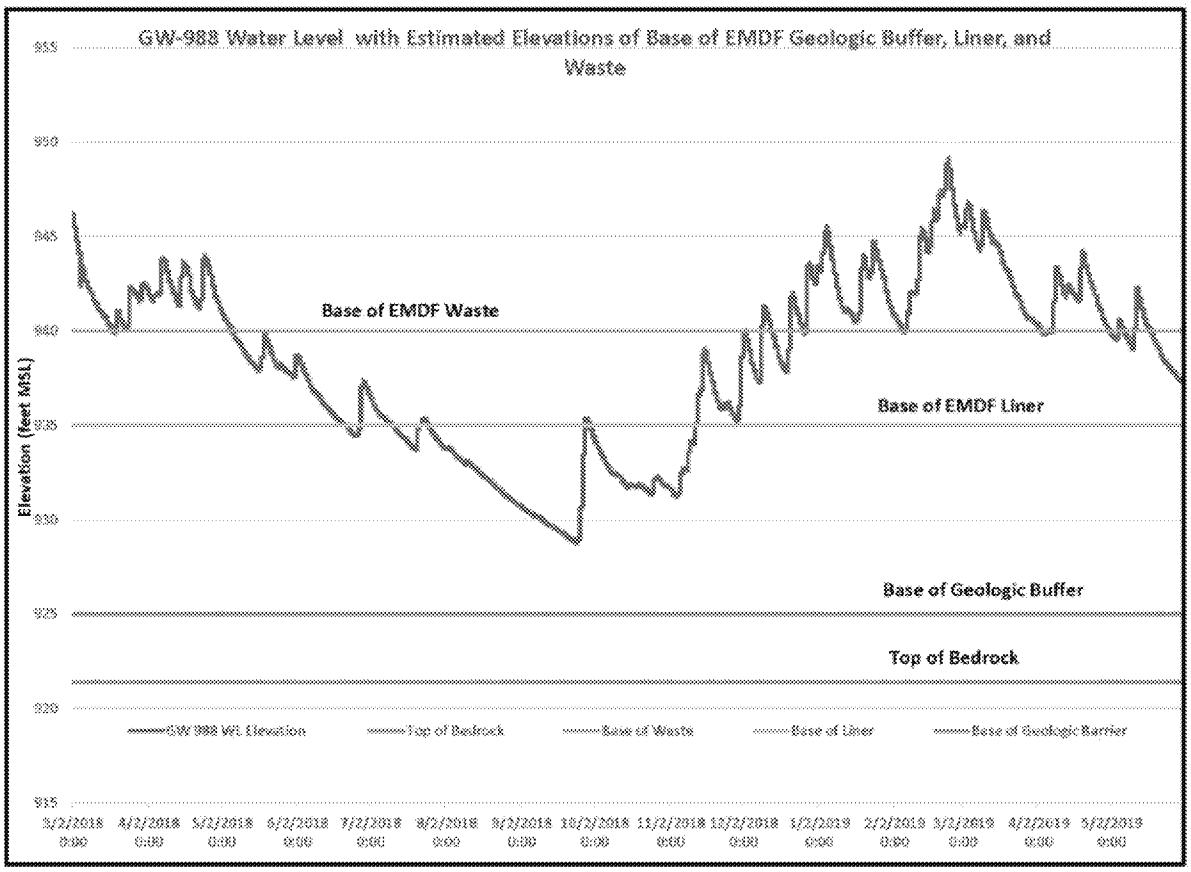
f) DOE plans to perform a field demonstration project in the knoll area where current groundwater elevations can be higher than the proposed multilayer base elevation.

2) Water level data collected for Technical Memorandum #2 (TM#2) available from the Oak Ridge Environmental Information System (OREIS) was compared with proposed EMDF Central Bear Creek Valley (CBCV) construction elevations estimated from *Figure 6-29 EMDF Cross-sections for CBCV Site* on page 6-74 of the last version of the *Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee (DOE/OR/01-2535&D5)* (EMDF RI/FS).

The two well pairs in areas of proposed excavation on the knoll for proposed Cells 1 and 2, under current conditions groundwater conditions show groundwater levels are sufficient to impact the geologic buffer year round and to impact the geomembrane liner and rise into the waste zone at certain times of the year. Please see the following figures. Top of bedrock in the following figures was estimated from borehole log auger refusal in borehole logs included in TM#2.



Deep Piezometer GW-982 screened from 102.1 - 112.1 ft-bgs (elevation 913.5 - 903.5 ft)
Shallow Piezometer GW-983 screened from 79.1 - 89.2 ft-bgs (elevation 936.4 – 926.4 ft)



Deep Piezometer GW-988 screen interval 61.9 - 71.9 ft-bgs (elevation 895.1- 885.1 ft)
OREIS does not include monitoring data for this period for shallow paired GW-989

3) The Site Groundwater Characterization fact sheet omits mention of upward groundwater movement. Upward movement of groundwater is shown in TM#2 and through evaluation of data collected for TM#2 included in the Oak Ridge Environmental Information System (OREIS). TM#2 also referenced the source for rainfall data and said rainfall data was also included in data evaluation.

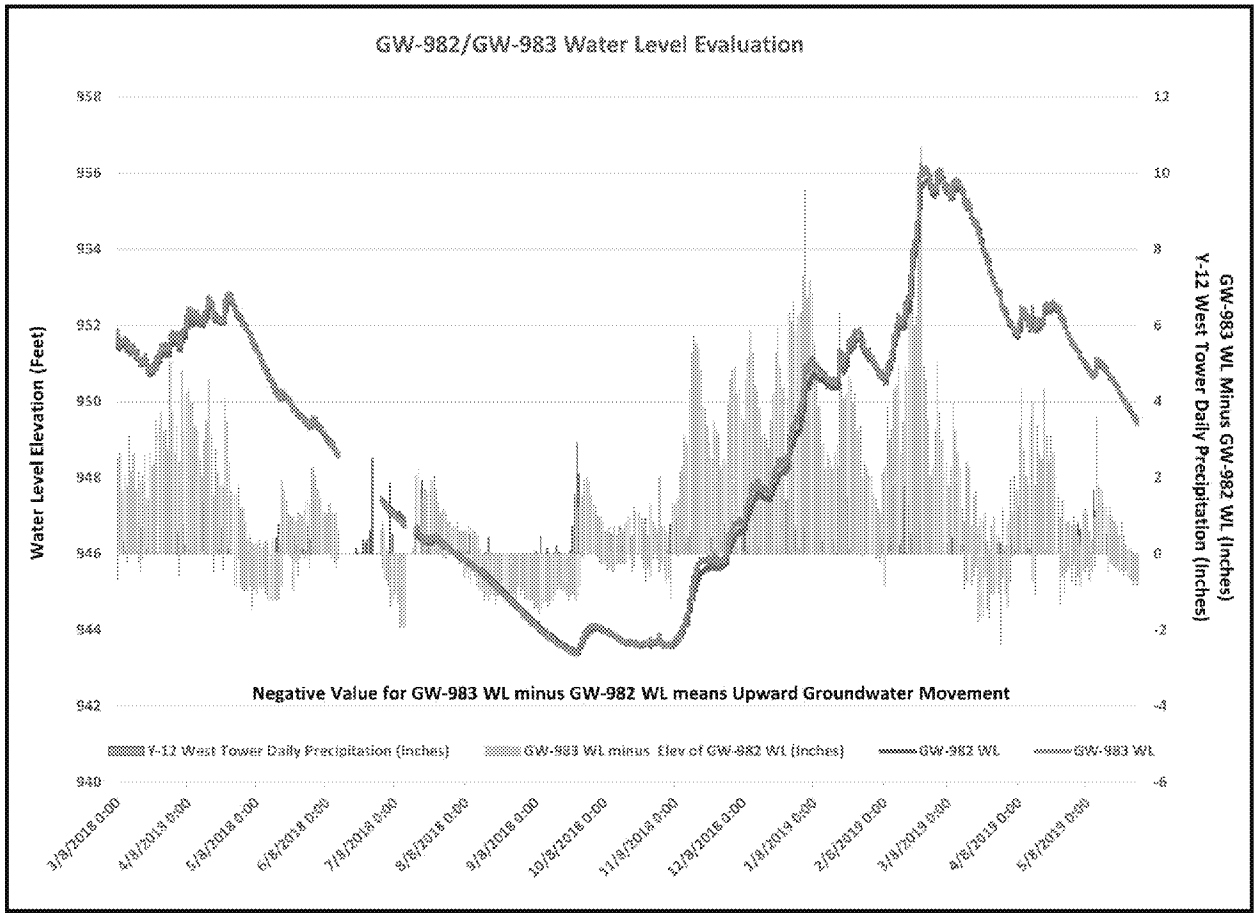
Select water level data for paired piezometers was used in TM-2 to develop Table 7.3 below. Up in the table means rising deeper groundwater.

Table 7.3. Vertical gradients at the CBCV site, September 2018 and February 2019

Piezometer	Mid-point of screen (ft bgs)	Total depth (ft bgs)	Vertical gradient during dry conditions, September 2018 (ft/ft)	Vertical gradient direction during dry conditions, September 2018	Vertical gradient during wet conditions, February 2019 (ft/ft)	Vertical gradient direction during wet conditions, February 2019
GW-978	64.5	80.0	0.12	Down	<0.01	Down
GW-979	31.3	37.8				
GW-980R	64.95	74.4	0.19	Down	0.28	Down
GW-981	27.1	34.0				
GW-982	107.1	126.5	<-0.01	Up	0.03	Down
GW-983	84.2	92.2				
GW-986	43.5	59.6	-0.01	Up	-0.02	Up
GW-987	21.1	27.9				
GW-988	66.9	78.5	0.02	Down	0.08	Down
GW-989	38.6	45.0				
GW-992R	41.85	55.5	-0.02	Up	-0.07	Up
GW-993	28.0	35.5				
GW-994	47.0	55.0	-0.07	Up	<-0.01	Up
GW-995	27.1	34.0				
GW-998	31.6	45.0	-0.01	Up	-0.03	Up
GW-999	15.3	22.0				

CBCV = Central Bear Creek Valley.
ft bgs = feet below ground surface.
GW = groundwater well.
R = replacement borehole.

The following figure derived by comparing water level data collected for TM-2 and available in OREIS for deeper and shallower piezometers GW-982/GW-983, shows that in addition to rising groundwater in the GW-982/GW-983 area during September 2018 dry conditions noted in TM-2 Table 7.3, under current conditions rising groundwater based on water levels was also recorded in TM-2 data up to an elevation of about 955 feet.

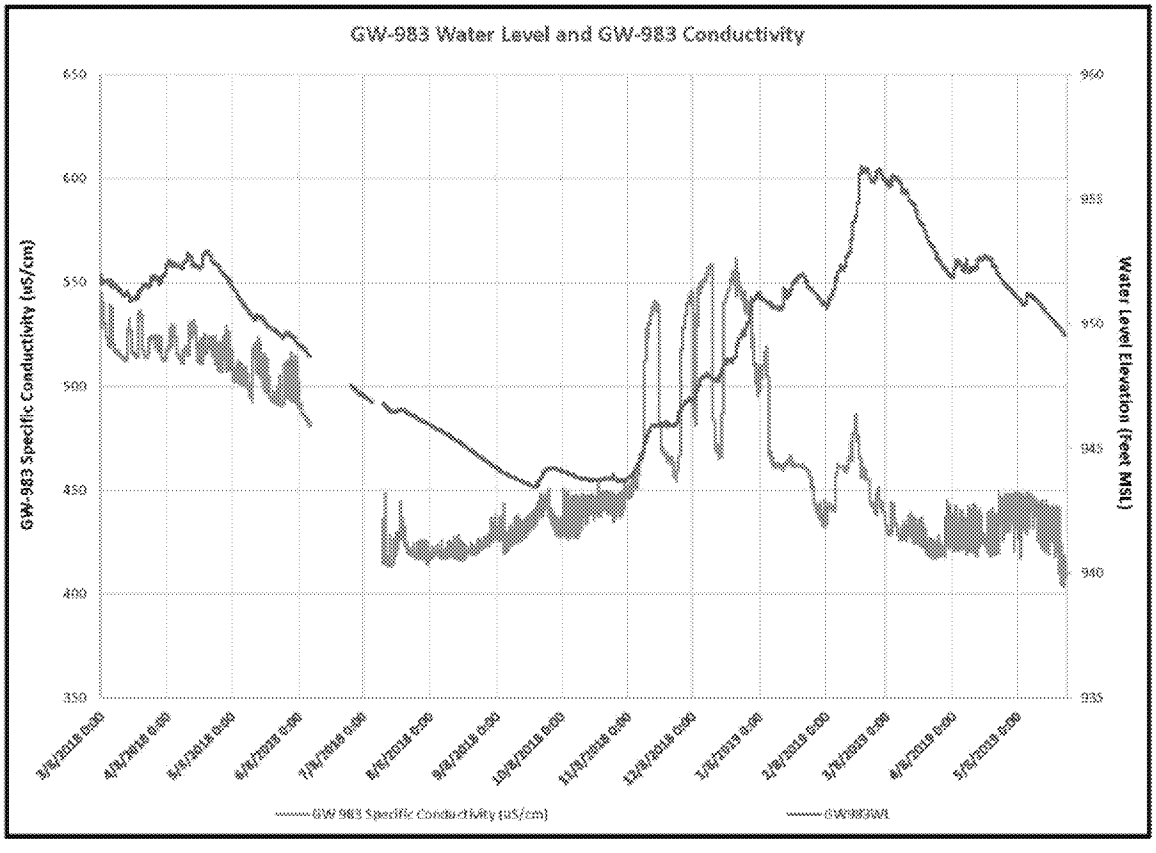


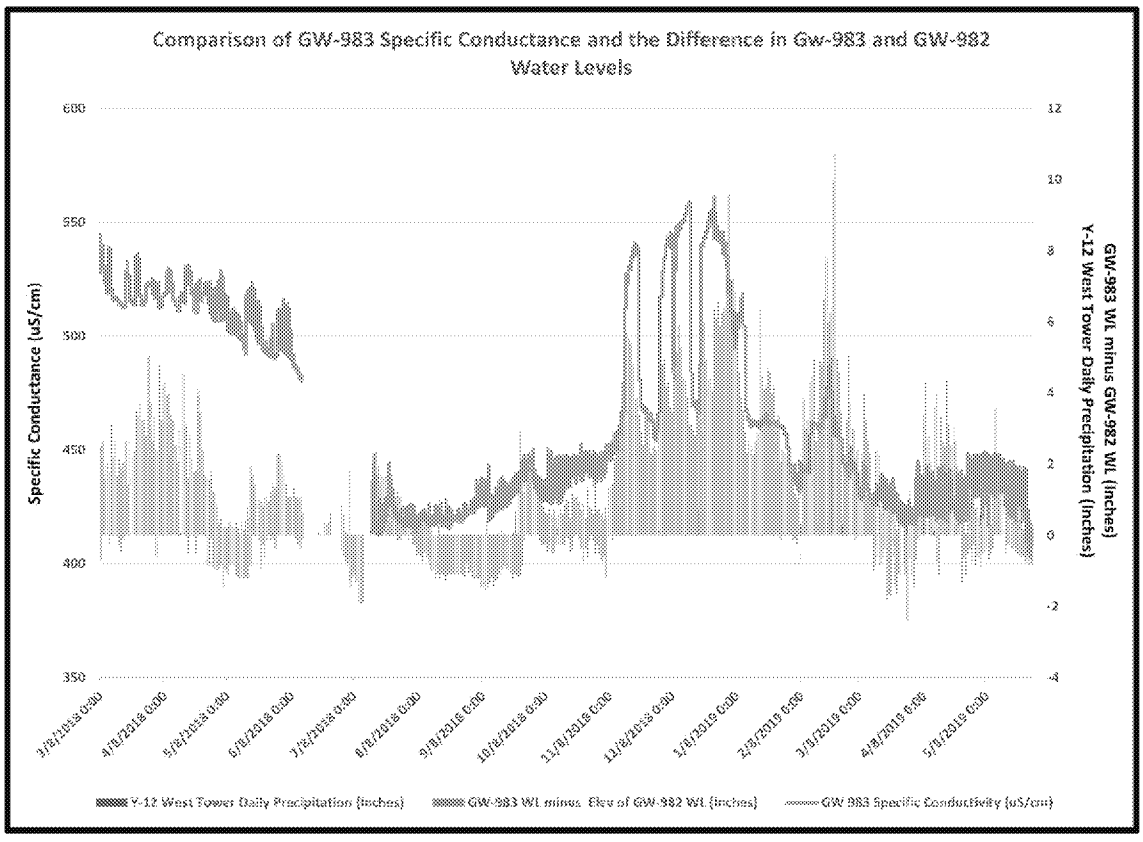
4) In addition to water level data, electrical conductivity, pH, and temperature data were also collected for TM#2. The following figures include:
   a) GW-983 electrical conductivity overlain on GW-983 water level;
   b) GW-983 electrical conductivity (specific conductance) overlain on the difference of water levels derived by subtracting the elevation of the water level in GW-982 from the elevation of the water level in GW-983;
   c) GW-983 electrical conductivity overlain over groundwater temperatures measured in GW-983, GW-982, and GW-988;
   d) Comparison of GW-983 groundwater temperature with air temperature measured at ORNL;
   e) GW-983 groundwater electrical conductivity overlain on GW-983 pH;
   f) Comparison of GW-982, GW-983, and GW-988 pH; and
   g) Comparison of GW-982, GW-982, and GW-988 electrical conductivity (i.e., specific conductance).

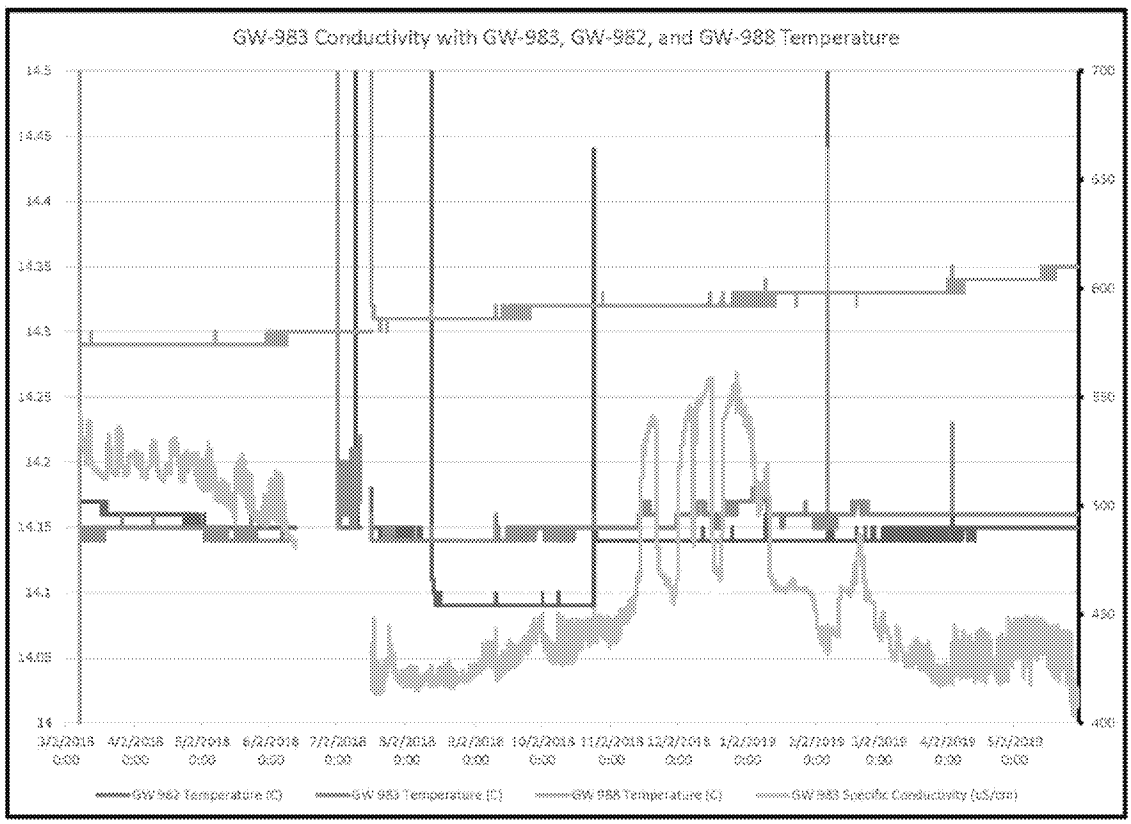
Evaluation of these figures shows:

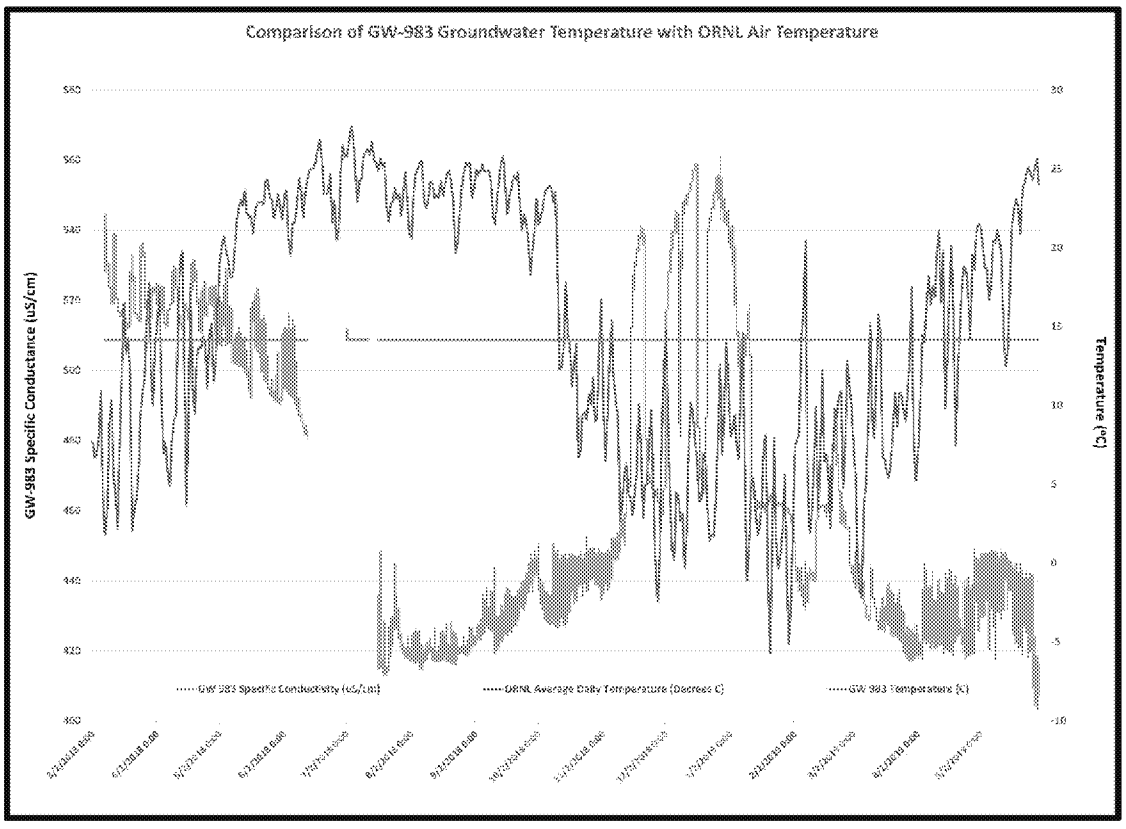
a) Increased electrical conductivity (i.e., specific conductance) in GW-983 observed from about November through March is real and is generally associated with an increase in groundwater temperature and a decrease in groundwater pH.
b) November through March are colder months and both air temperature at ORNL and groundwater temperature for deeper piezometer GW-982 have temperatures lower than the high conductivity groundwater entering GW-983. Increased temperature of groundwater associated with the higher electrical conductance groundwater during late fall and winter shows the source of the influx of higher electrical conductance groundwater is neither GW-982 nor infiltrating rainwater.
c) Deeper piezometer GW-982 also has a higher pH than GW-983, so again it's not the source of lower pH groundwater entering GW-983.
d) The higher electrical conductivity groundwater entering GW-983 appears more like groundwater measured in GW-988 than either rainwater or GW-982.

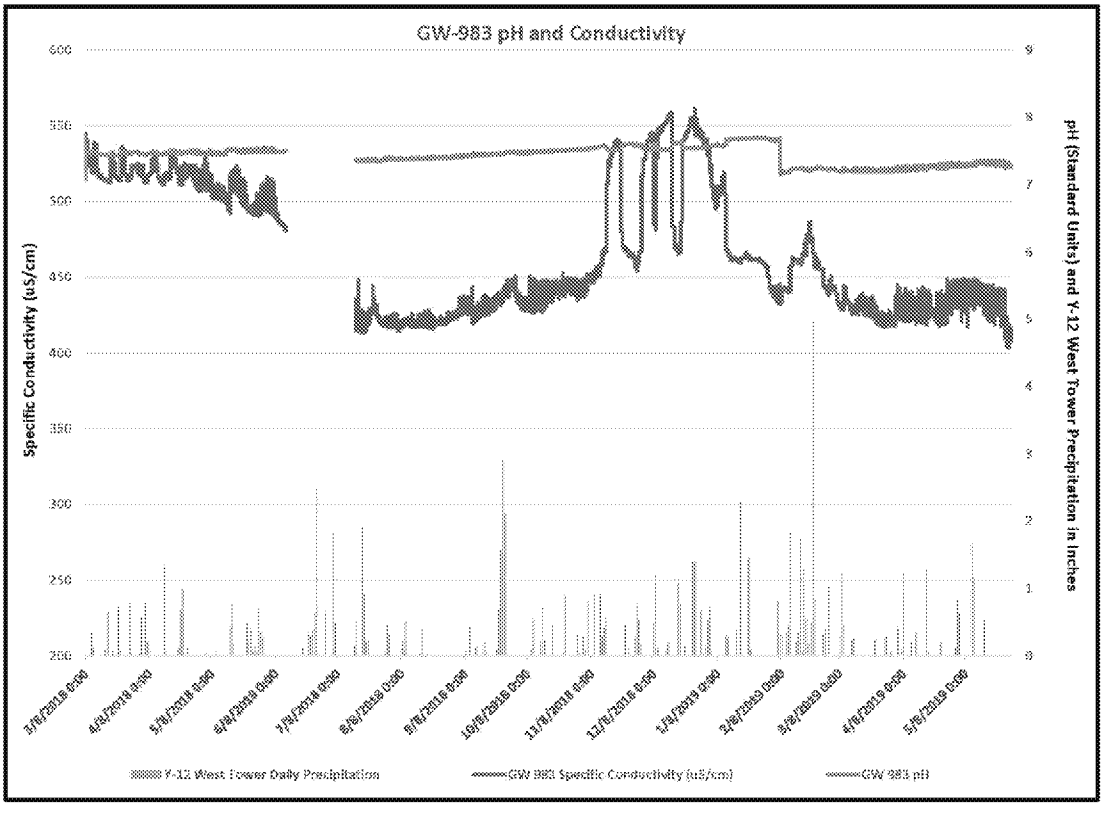
This analysis concludes the higher electrical conductivity, lower pH, higher temperature groundwater that entered GW-983 during late fall and winter 2018/2019 is real, not bad data, and was neither infiltrating rainwater nor GW-982 groundwater. Where electrical conductivity begins to drop off in January and February may be due to dilution from infiltrating rainwater.

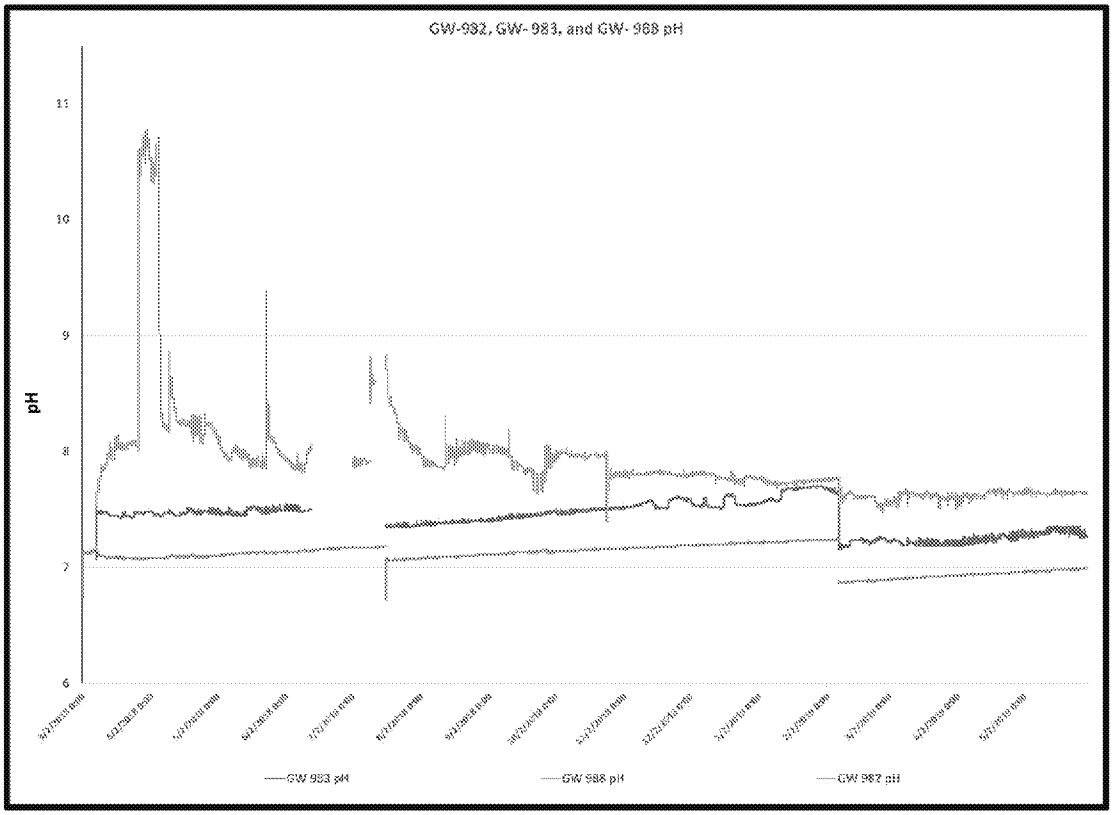


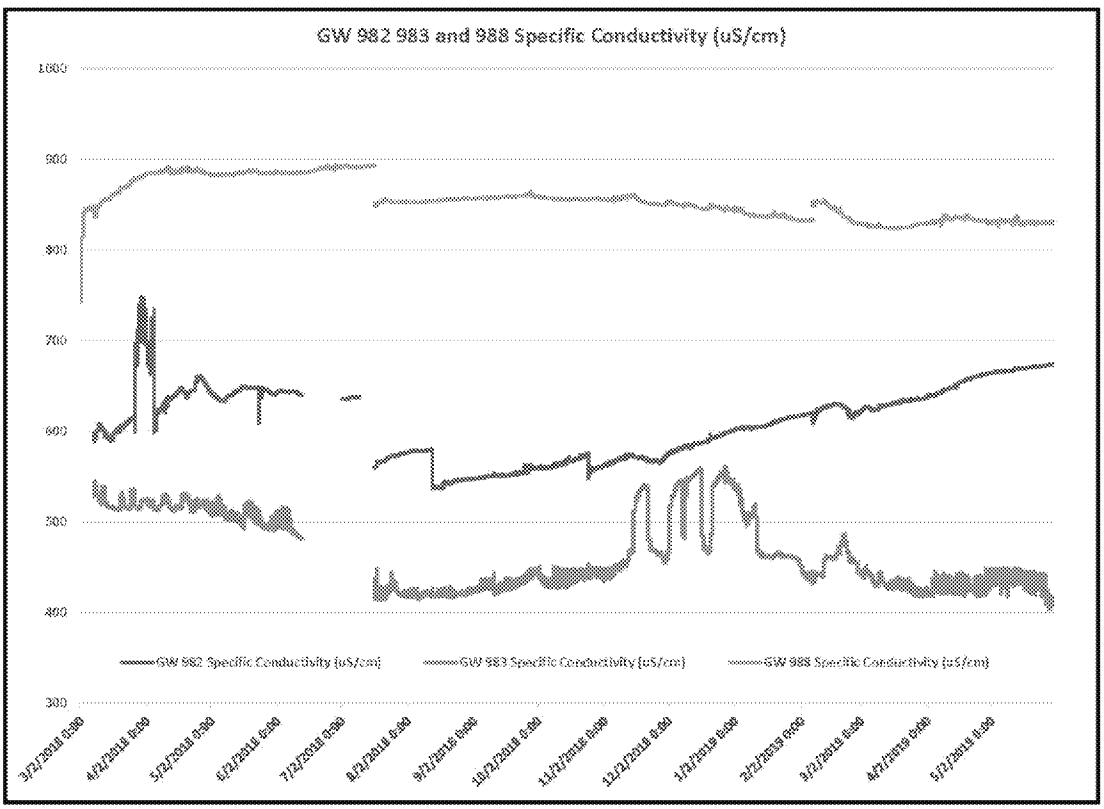

Comparison of GW-983 Specific Conductance and the Difference in Gw-983 and GW-982 Water Levels
Specific Conductance (uS/cm)
GW-983 WL minus GW-982 WL (inches)
Y-12 West Tower Daily Precipitation (inches)
600
550
500
450
400
350
12
10
8
6
4
2
0
-2
-4
3/8/2018 0:00
4/8/2018 0:00
5/8/2018 0:00
6/8/2018 0:00
7/8/2018 0:00
8/8/2018 0:00
9/8/2018 0:00
10/8/2018 0:00
11/8/2018 0:00
12/8/2018 0:00
1/8/2019 0:00
2/8/2019 0:00
3/8/2019 0:00
4/8/2019 0:00
5/8/2019 0:00
Y-12 West Tower Daily Precipitation (inches)
GW-983 WL minus Elev of GW-982 WL (inches)
GW 983 Specific Conductivity (uS/cm)


GW-983 Conductivity with GW-983, GW-982, and GW-988 Temperature
14.5
14.45
14.4
14.35
14.3
14.25
14.2
14.15
14.1
14.05
14
700
650
600
550
500
450
400
3/1/2018 0:00
4/1/2018 0:00
5/1/2018 0:00
6/1/2018 0:00
7/1/2018 0:00
8/1/2018 0:00
9/1/2018 0:00
10/1/2018 0:00
11/1/2018 0:00
12/1/2018 0:00
1/1/2019 0:00
2/1/2019 0:00
3/1/2019 0:00
4/1/2019 0:00
5/1/2019 0:00
GW 982 Temperature (C)
GW 983 Temperature (C)
GW 988 Temperature (C)
GW 983 Specific Conductivity (uS/cm)


Comparison of GW-983 Groundwater Temperature with ORNL Air Temperature
GW-983 Specific Conductance (uS/cm)
Temperature (°C)
GW 983 Specific Conductivity (uS/cm)
ORNL Average Daily Temperature (Decrees C)
GW 983 Temperature (C)


GW-983 pH and Conductivity
Specific Conductivity (uS/cm)
pH (Standard Units) and Y-12 West Tower Precipitation in Inches
Y-12 West Tower Daily Precipitation
GW 983 Specific Conductivity (uS/cm)
GW 983 pH


GW-982, GW- 983, and GW- 988 pH
pH
11
10
9
8
7
6
GW 983 pH
GW 988 pH
GW 982 pH


GW 982 983 and 988 Specific Conductivity (uS/cm)
1000
900
800
700
600
500
400
300
GW 982 Specific Conductivity (uS/cm)
GW 983 Specific Conductivity (uS/cm)
GW 988 Specific Conductivity (uS/cm)

5) GW-983 has a sand pack from a depth of 74.1 to 91.5 ft -bgs (feet below ground surface) and the screen in GW-983 is from 79.1 to 89.2 ft-bgs. The GW-982 borehole log[i] shows that bedding dips 45 to 50 degrees and the description of the core changes at a depth of about 73.3 feet. Above this the core description includes numerous entries of fractured to intensely fractured intervals with iron oxide coatings indicating weathering, water movement, and that the fractures were not mechanically induced by drilling. Angular piece with slickensides from 65.9 to 66.5 may indicate faulting. The top of the GW-983 sand pack is immediately below the change in core description. Given the electrical conductivity with associated temperature and pH discussion in another comment with the core description it is plausible that deeper groundwater moves upward through dipping beds or fault described in the borehole immediately above the GW-983 sand pack and screen and impacts shallow piezometer GW983. This would give a false impression of a downward groundwater gradient.
6) Piezometer pair GW-988 and GW-989 possibly drilled through a fault(s). Borehole descriptions[ii] of bedding turning from a 45-degree dip to near vertical with additional discussion of slickensides perpendicular to bedding, some limestone beds being highly deformed to almost brecciated, and possibly slightly overturned beds appear to indicate faulting. In this case both deep piezometer GW-988 and shallow piezometer GW-989 are screened in or near potentially faulted intervals. Shallow piezometer GW-989 sand pack also appears to across the saprolite bedrock contact allowing shallow groundwater at the saprolite bedrock contact to enter the piezometer. TM-2 also includes the following figure with a statement suggesting deeper groundwater rises with rainfall.

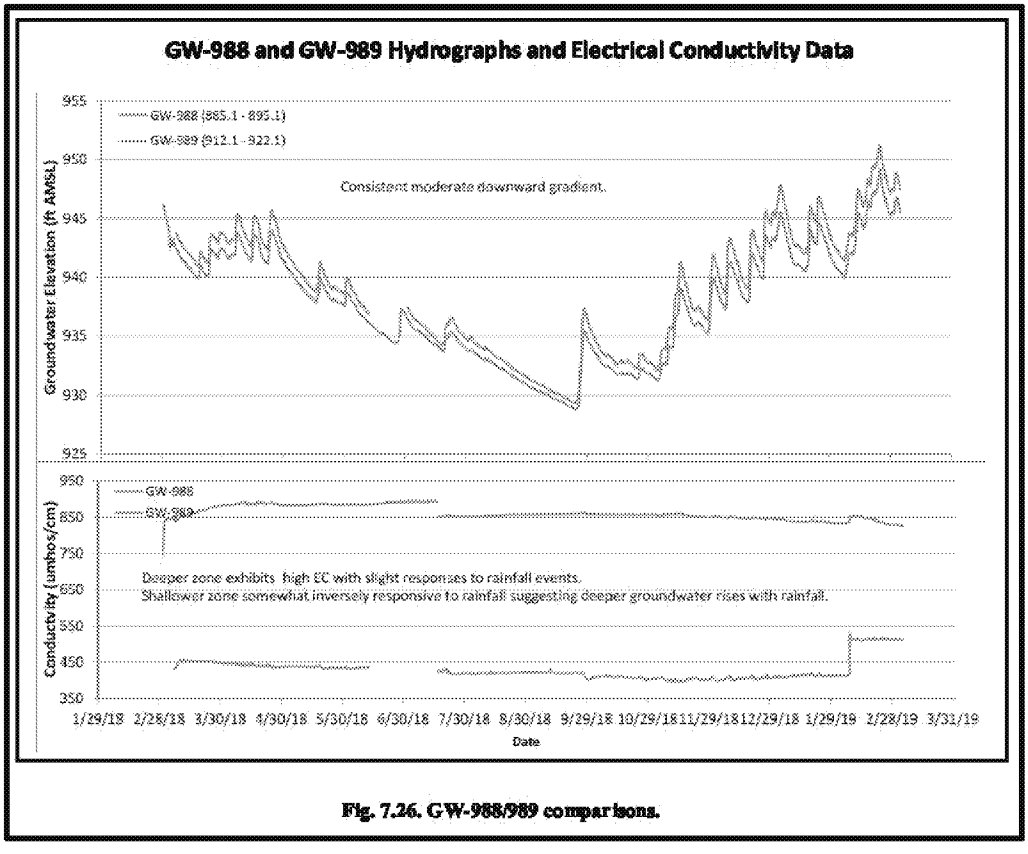
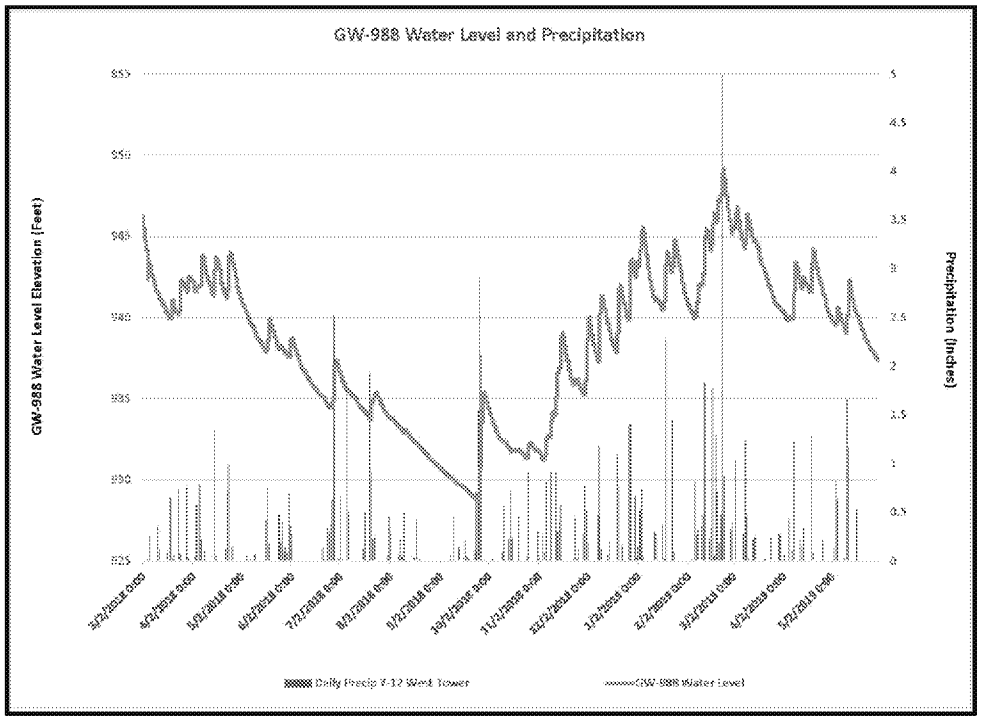
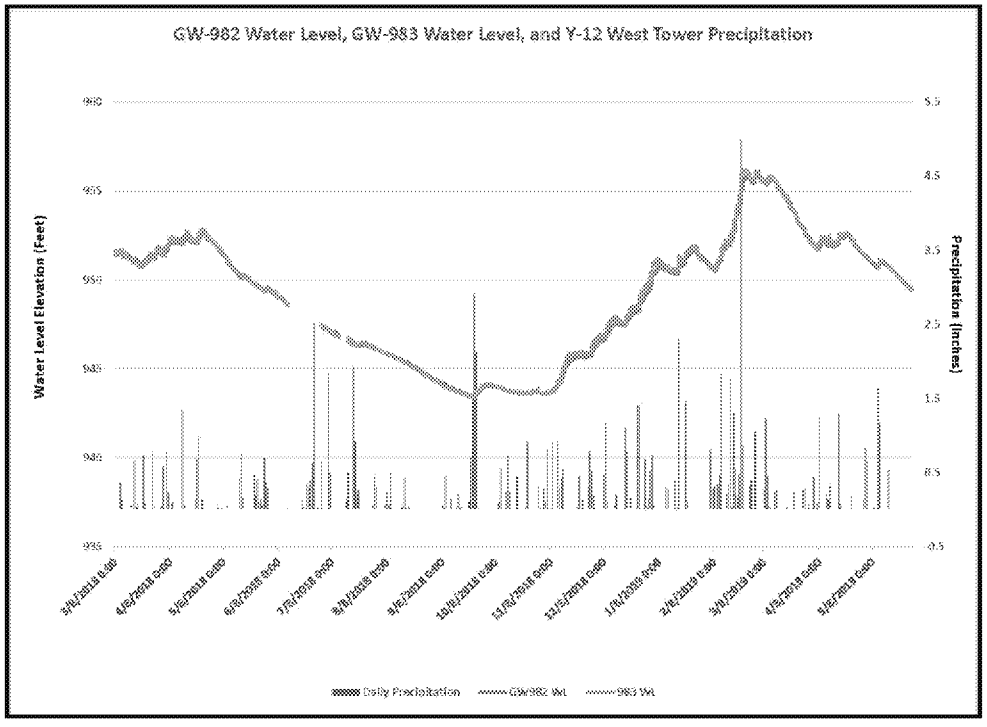


Fig. 7.26. GW-988/989 comparisons.

7) The Site Groundwater Characterization fact sheet correctly noted the water level response to rainfall. However, rainfall response in GW-988 was quick and response in GW-982/GW-983 was delayed.





8) The Site Groundwater Characterization fact sheet also discusses conducting a field demonstration project to inform the design.
   a) TM#2 suggests that auger refusal represents the top of bedrock. Using this criteria, GW-982 and GW-983 groundwater levels represented in TM#2 are always below the top of bedrock. Groundwater at or below the top of bedrock in moderate to steeply dipping strata can be expected to typically move along geologic strike (i.e., bedding) and fractures. Thinking about water levels in GW-982 and GW-983 as a water balance, water enters the system as rainwater percolating into the ground from above and as deeper groundwater moving upward. The accumulated water leaves the system through conduits likely along geologic strike and through fractures that transmit water. Under this conceptual model, groundwater declines to a level where water entering the system and water leaving the system are in balance. Then at the start of the rainy season, water enters the system both as infiltrating rainfall and upward moving groundwater and maintains that water level until the conduits are full. When the conduits cannot transmit all the water, the water level rises until additional overflow conduits are sufficient to balance water entering the system. Groundwater rises until water entering the system equals water exiting the system. As rainfall decreases, water level drops as conduits continue to transmit water out of the system
   b) Under this site conceptual model, the proposed field demonstration may imply how high deeper groundwater moving upward may rise in the GW-982/GW-983 area under current conditions, if the conduit system is not disturbed. If the conduit system is either removed by excavation or restricted by the weight of the landfill, it is likely deeper groundwater rising under the proposed landfill will be different than projected by the filed demonstration.
   c) Under this site conceptual model, the proposed field demonstration may indicate whether there is sufficient "epikarst" in the area of GW-988 to prevent groundwater from rising into the proposed geologic buffer. Similar to the comment above, if the conduit system is either removed by excavation or restricted by the weight of the landfill, it is likely deeper groundwater rising under the proposed landfill will be different than projected by the filed demonstration.
9) Pneumatic piezometers used at EMWMF required a lot of interpretation and explanation. Even with the field demonstration project, instead of pneumatic piezometers, a method(s) of direct measurement of groundwater levels at the proposed EMDF site is needed.
10) The Site Groundwater Characterization fact sheet also references waivers and exceptions for 2 TSCA rules and one TDEC NRC rule.
   a) The fact sheet references a TSCA rule exception or waiver that there is no hydraulic connection between the site and standing or flowing surface water. As state in comments on PCBs to the Water Quality Protection for Bear Creek fact sheet the existing EMWMF is authorized to accept TSCA PCB waste and control of discharge of PCBs to surface water has not been a priority for almost 20 years. The Focus Feasibility for Water Management even screened PCBs out from being a contaminant of concern for the proposed EMDF based on the number of detections of PCBs where detection and reporting limits were 100 to 1000 times higher than promulgated recreational use water quality criteria. Isolation of the EMDF site from surface water is needed during landfill operations, closure, and post closure to protect human health and the environment from PCB pollution and this applicable requirement should not be waived.

b) The fact sheet also references a TSCA rule exception or waiver that the bottom of the landfill liner system be at least 50 feet from the historical high-water table. As shown in the above comments, the high-water table in both the GW-982/GW-983 and GW-988 areas rose to elevations of the proposed liner and even to proposed waste elevations during monitoring for TM#2. Irrespective of the results of the field demonstration project or the thickness of the multi-layer base, it should be hard to rationalize justification for waiving this applicable TSCA requirement at a location with rising groundwater.

c) A waiver or exception from TDEC NRC disposal siting rule that "The hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site" is requested. It is my understanding that this requirement is meant to ensure that, if there were a release, there would be sufficient real estate to perform corrective action at the site prior to discharge of groundwater to the surface. That is not the basis for which a waiver is requested or justified in this fact sheet. Prior to authorizing a waiver, it is suggested that the purpose for the regulation be established and then see if the justification achieves the purpose of the regulation. If the purpose is to have sufficient room for corrective action, a discussion of engineered liner and limits on waste acceptance criteria (WAC) do not meet the mark. Further, WAC has not been shown to be protective of human health based on CERCLA.

11) TDEC Rule 0400-20-11-.17(1)(g) "*The disposal site must provide sufficient depth to the water table that ground water intrusion, perennial or otherwise, onto waste will not occur. ... In no case will waste disposal be permitted in the zone of fluctuation of the water table.*" As shown by evaluating TM#2 groundwater elevation data placed in OREIS after the previous public comment period, disposal proposed in the Remedial Investigation and Feasibility Study does not meet this relevant and appropriate requirement and no waiver for this requirement was requested.

These comments are respectfully submitted by:

Robert (Andy) Binford, PG
Retired Former TDEC Division of Remediation Division Director and Environmental Fellow

E-mail copy to:

Acting Assistant Administrator Barry N. Breen, EPA
Breen.Barry@epa.gov

Carrol Monell, EPA Region 4
Monell.Carol@epa.gov

Laura Wilkerson, DOE
Laura.Wilkerson@orem.doe.gov

Commissioner David Salyers, TDEC
David.Salyers@tn.gov

Amanda Garcia, SELC
agarcia@selctn.org

Stephanie Biggs, SELC
sbiggs@selctn.org

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Eagon & Associates, Inc.

EMDF Characterization Project Oak Ridge, TN	**BOREHOLE LOG**	Boring Number GW-982

Remarks:

Depth (feet)	Sample Method	Sample Recovery (feet or %)	Blows/6 in or RQD	SAMPLE DESCRIPTION	Graphic Log	Remarks	USCS
46	NS			Light yellowish brown (2.5Y 6/3 - 6/4) and light olive brown (2.5Y 5/3 - 5/6) highly weathered SHALE (SAPROLITE). (Cont'd.)		No indication of water on drilling rods or sampler to 47.3'.	CL
	SS-24	0.2	50/1	Trace calcite appears to be 1 to 5 mm fracture infilling. Sample is pulverized.		SS-24 Strong reaction with HCl.	
47	NS			Change at 47.3'.			
48	C-1	1.5' 32%	0%	Olive gray to dark olive gray (5Y 4/2 - 3/2) and gray dark gray (5Y 5/1 - 4/1) SHALE and LIMESTONE. Limestone beds appear silty in places and may classify as a calcareous siltstone. Thinly bedded, sample is very broken (40° bedding angle). Trace white calcite veins (up to 5 mm). Trace black and brownish yellow iron/manganese oxide precipitate along bedding breaks and possible fractures. Gray-grayish beds are limestone. Olive colored beds are generally shale. Highly weathered. Moderate to very strong strength. Most of the lost recovery is expected to be within shale beds that have low field strength. C-1 recovery, bottom piece has reddish brown interbeds (<0.05'). Beds appear deformed with slight displacement along healed fractures (white calcite in-fill). Bottom of recovery has a fracture face that is perpendicular to bedding.		1128, 2/8/18, Auger refusal at 47.3'. 1308 Borehole measured dry at 46.2'. Set up to core. Set temporary 4 1/2" steel flush threaded casing, HQ3 core, water circulation. 1425 Start washing core bit to depth. C-1 47.3' - 52.0' 1450-1536. Cannot position C-1 core loss, sample is too broken. No reaction with HCl within shale, strong reaction with calcite fracture infilling and within limestone beds.	
52	C-2	2.8' 100%	0%	Below 52.0' higher percentage of shale, mostly shale. Limestone beds generally have calcite veins or healed fractures. Continues to be highly weathered. Predominate olive gray to dark olive color. Trace thin limestone interbeds below 54.1'.		C-2 Run, fractured throughout, faces are coated with iron and/or manganese oxide. C-2 52.0' - 54.8' 1555-1655. C-3 54.8' - 55.8' 1710-1730. End 2/8/18, 1730 at 55.8'. Water level at 10.1', 1745 most if not all drilling water was recirculated during drilling.	
55	C-3	1.0' 100%	0%				
56	C-4	1.1' 92%	0%	Below 55.8 slight increase in brown color. Some dark olive gray to olive gray (5Y 4/2 - 3/2). Primarily shale or mudstone composition. Bedding angle is approximately 40°. Continues to be thinly bedded with limestone partings and thin seams (<0.05'). Moderate field strength. Limestone layers are strong to very strong. Moderately decomposed/weathered.		Begin 2/9/18 0830, driller changing out bit style, HQ3 still. Start coring at 0955. 0840, WL: 16.82 from GS. No reaction with HCl. Continues to be highly fractured with iron oxide precipitates on fracture faces. Breaks along bedding planes and angular fractures. Intensely to moderately fractured. Sample is generally very broken and fracture orientation and fracture traces are hard to follow.	
57	C-5	2.7' 54%	0%	Below 57.4' Trace to few dark greenish gray to very dark greenish gray (5GY 4/1 - 3/1) layers. Becoming less weathered. Stronger olive color associated with weathered areas. Core is very broken from 58.0' - 59.7'. Lost core probably from bottom of run. Below 58.4' limestone interbeds are deformed (soft sediment) irregular surfaces and thickness, generally less than 0.1' thick. Near 59.7', trace pink calcite, up to 5mm thick, appears to be fracture infilling.			
62	C-6	4.5' 90%	0%	Below 62.4' predominately dark gray to very dark gray (N 4/ - 3/) with trace olive gray/dark olive gray (5Y 4/2 - 3/2) zones associated with weathered areas. Trace gray (5Y 6/1 - 5/1) partings/thin limestone seams. Continues to be intensely fractured. 64.6' - 64.8', 65.2' - 65.4', 65.6' - 65.8' bedding plane fractures/breaks with iron oxide and trace calcite. 65.6' - 65.8' Fracture is polished (slickenside). 65.9' - 66.5' Recovery is very broken, some angular pieces with slickenside surfaces.		C-6 Run, bedding angle varies between 45° to 50° limestone seams are typically deformed and have wavy surfaces/contacts. 62.9' - 63.4' Oxidized bedding break, 3/4" olive gray weathering have faces coated with iron oxide. 63.6' - 64.0' Bedding break, calcite coating on face, no oxidation . Possible indication of saturation. Broken oxidized fractures above and below.	
67	C-7	2.3' 46%	0%	Below 67.0' primarily limestone and siltstone recovery. Few shale seams. Lost recovery (C-7 run) may be mostly shale. Highly broken interval, intensely fractured/broken. Fracture/bedding break faces are all oxidized with mostly iron oxide coatings; trace black manganese oxide. Mostly olive gray to dark olive gray (5Y 4/2 - 3/2). Some dark gray to very dark gray areas.		C-4 55.8' - 57.0' 0955-1010. C-5 57.0' - 62.0' 1018-1124. C-6 62.0' - 67.0' 1133-1220. C-7 67.0' - 72.0' 1429-1541.	

BOREHOLE LOG V2 OAK RIDGE.GPJ CONTAINER CRAFT TEMPLATE WITH PID.GDT 4/4/18

Eagon & Associates, Inc.

EMDF Characterization Project Oak Ridge, TN	**BOREHOLE LOG**	Boring Number GW-982

Remarks:

Depth (feet)	Sample Method	Sample Recovery (feet or %)	Blows/6 in or RQD	SAMPLE DESCRIPTION	Graphic Log	Remarks	USCS
71	C-7	2.3' 46%	0%	Interbedded olive gray to dark olive gray (5Y 4/2 - 3/2), dark gray to very dark gray (N 4/ - 3/) SHALE and LIMESTONE. (Cont'd.) Trace to few limestone seams (<0.2' thick). 72.7' - 73.1', 0.15' Thick silty limestone seam. Strong reaction with HCl.		Lost recovery in C-7 run is assumed to be shale. Bedding angle is between 45° - 50°.	
72	C-8	1.2' 100%	0%	Highly fractured and broken. Generally has associated iron oxide coatings. Trace calcite precipitates.		Most of C-8 recovery is shale. C-8 72.0' - 73.2' 1555-1621.	
73				Change at 73.3'.		73.3' - 73.5; fracture oriented perpendicular to bedding. Face appears oxidized.	
74	C-9	3.8' 100%	16%	Dusky red (5R 3/3) OOLITIC LIMESTONE. Trace to few glauconite nodules (~1mm). Red color possibly associated with hematite. Massive. Field strength is strong, competent. Trace white calcite healed fractures. Fresh to slightly weathered. Change at 74.0'.		End 2/9/18, 0710 at 77.0' WL at 1724 = 23.72' from ground. C-9 73.2' - 77.0' 1633-1710. 2/10/18, 0805, WL = 63.0'.	
75				Very dark gray to black (N 3/ - 2 1/2/) SHALE. Thinly bedded, ~45° - 50° angle. Trace gray ~1mm siltstone partings. Fresh. Intensely fractured or broken, mostly along bedding planes (some may be mechanical). Unweathered/no oxidation.		Begin 2/10/18, 0830, 45°F, overcast, tract light rain. Continue HQ core, using core barrel liner.	
76							
77				Below 77.0' bedding angle is between 55° - 60°. Moderately to intensely fractured.		C-10 77.0' - 79.9' 0833-0920.	
78	C-10	2.9' 100%	35%	77.0' - 77.3' Bedding break, slickenside surface. No weathering or precipitates. 77.7' - 77.9' Bedding break surface has white noncarbonate precipitate, trace fine (<1mm) pyrite. Slickenside surface. 77.9' - 78.2' Bedding break, slightly polished surface. Trace thin (<1mm) calcite and clay (maybe from drilling) on face. No oxidation. Maybe open. 79.0' - 79.3' Set of bedding breaks, polished (slickenside) surfaces. Within interval, perpendicular fracture appears healed with white noncarbonate infilling (hairline). Change at 79.9'.		Broken zones are identified fractures in C-10 interval appear to be mechanical, probably associated with wedging and difficulty with sample. Feeding, typically core wear indicates core was turning. Bottom of C-10 recovery mechanically fractured (broken), bit plugged at end of run. End 2/10/18, 1004, rain, at 80.2'.	
79							
80							
81	C-11	1.5' 71%	0%	Interbedded gray to very dark gray (N5/ to N3/) SHALE and LIMESTONE. Thinly bedded, generally between 0.1' - 0.3'. Limestone and shale partings are common. Shale beds are typically darker gray and soft while limestone beds are lighter gray and hard. Bedding appears to vary between 50° to 60°. Trace healed fractures, while calcite filled, generally oriented perpendicular to bedding, hairline to 2 mm width. Unweathered to slightly weathered (fresh). Mostly shale, 20 - 30% limestone.		Begin 2/12/18, 0920 continue C-11 run. 0907 WL = 35.05' from GS. 45°F, Overcast, wet. C-11 Run, lost recovery mostly from bottom of run. ~55° - 60° bedding angle At 81.4' fracture at 90° to bedding, iron oxide on face. Adjacent rock is not oxidized. 83.1' - 83.5' Broken zone, probable fracture or fractures, no oxidation. 83.3' - 83.5' 1/4" to 1/2" thick pink calcite filled fracture. 84.7' - 84.9' Set of fractures 45° to bedding angle, surfaces have slickensides. No precipitate or oxidation. C-11 79.9' - 82.0' 0920-0935. C-12 ~50° bedding angle.	
82							
83							
84	C-12	4.2' 84%	38%	Below 82.0' primarily shale, trace lighter (gray) limestone or siltstone partings (<1/4"). 85.0' - 85.9' Bluish gray to dark bluish gray (5PB 5/1 to 4/1) Interclastic Limestone Seam - elongated elliptical, clasts oriented parallel with bedding (long axis), up to 1" high and 1 3/4" wide. 45° - 50° bedding angle. Hard, unweathered except for lower contact which is oxidized yellowish brown. Trace fine (<1 mm) glauconite nodules.			
85							
86							
87				Below 87.8' becomes interbedded limestone and shale, thinly bedded, somewhat deformed. Trace glauconitic beds/partings. Change at 87.8'.		At 87.8' oxidized (iron oxide) bedding contact. Strong reaction with HCl.	
88	C-13	3.2' 64%	35%	Bluish gray to dark bluish gray (5PB 5/1 - 4/1) LIMESTONE. Fine grained. Few 1 mm or less glauconite nodules. Trace stylolites, dark gray to black, jagged, trace. Thinly bedded. Fresh. Basal contact has rip up clasts, elliptical and elongated with bedding. Becoming interclastic. Change at 89.5'.		At 88.0' fracture, 45° to bedding, oxidized (iron oxide on face).	
89							
90				Interbedded very dark gray to black (N 3/ - N 2 1/2) SHALE and gray to dark gray (N 5/ - 4/) LIMESTONE. Generally thinly bedded (0.1' or less). Trace white calcite filled fractures (healed). Limestone seams are generally deformed, wavey, uneven bedding. Fresh, no oxidation. Intensely broken along bedding planes, most are mechanical. Limestone is hard to moderately hard. Shale is soft. 92.0' - 93.7' Predominately shale, trace limestone partings.		Limestone reacts strong with HCl. Shale has no reaction. 92.0' - 92.3', 93.1' - 93.4', and 93.4' - 93.7' Bedding plane breaks, slickenside surface. No oxidation or precipitates.	
91							
92							
93	C-14	4.0' 100%	10%	Below 93.7' trace bioturbation.		92.85' - 92.95' ~45° fracture, slickenside surface. No oxidation or precipitates. 45° - 50° Bedding angle. C-12 82.0' - 87.0' 1044-1105. C-13 87.0' - 92.0' 1140-1159.	
94							

BOREHOLE LOG V2 OAK RIDGE.GPJ CONTAINER CRAFT TEMPLATE WITH PID.GDT 4/4/18

ii

Eagon & Associates, Inc.

EMDF Characterization Project Oak Ridge, TN	**BOREHOLE LOG**	Boring Number GW-989

Remarks: Borehole installed for the collection of geotech samples and installation of shallow piezometer.

Depth (feet)	Sample Method	Sample Recovery (feet or %)	Blows/6 in or RQD	SAMPLE DESCRIPTION	Graphic Log	Remarks	USCS
21				SHALE (SAPROLITE). (Cont'd.)			
22				Below 22.0' auger cutting returns are very moist. No free water.			
23							
24							
25							
26	NS						
27							
28							
29				Below 30.0' auger cutting returns are wet.		C-1 32.0' - 35.6' 1630-1701.	
30				Contact with underlying interbedded shale and limestone is higher than 32.0'.		C-2 35.6 - 36.7' 0930-0941.	
31						C-3 36.7' - 40.0' 0952-1050.	
32				Change at 32.0'.		C-4 40.0' - 45.0' 1108-1130.	
33				Interbedded dark gray to olive gray (5Y 4/1 - 4/2) SHALE and LIMESTONE. Some of the limestone seams may actually classify as calcareous siltstone. Thinly bedded, generally <0.1' beds and partings are not uncommon. Bedding angle is 45°. Limestone seams are hard and react strongly with HCl. Microcrystalline to fine crystalline. Shale seams are soft, do not react with HCl. Moderate to highly decomposed. Intensely fractured.		Contacts between limestone and shale beds are wavey/deformed. Soft sediment deformation trace bioturbidation. Approximately 40% to 60% limestone.	
34	C-1	2.9' 80%	13%				
35				With depth picking up gray color hues, becoming unweathered. Below 33.3' consistent gray to very dark gray (N 5/ - N 3/) color. Fresh to slightly decomposed. Limestone seams have lighter gray color hues. Becoming unweathered/competent.		32.0' - 33.6' Most bedding breaks are oxidized with iron oxide precipitates on fracture surfaces.	
36	C-2	1.1' 100%	0%				
37				33.5' - 34.4' Primarily limestone, trace shale partings and thin seams. Bedding contacts are deformed and bioturbated.		34.1' - 34.3' Broken zone, bedding break and fracture perpendicular to bedding. Oxidized with iron oxide precipitates on fracture faces. End 2-27-18, 1701 at 35.6'. 2/28/18, 0810 WL = 5.4', 49°F, Light rain. Start coring at 0930.	
38	C-3	1.5' 45%	30%	Below 35.6' oxidized zones/fractures are rare and called out where observed. Continues to be thinly bedded with common mechanical breaks at shale/limestone bedding contacts. Secondary mineralization along breaks is generally not observed.		The increase in white calcite filled fractures below 36.0' appears to correlate with the increase in the bedding angle.	
39						41.9' - 42.3' Broken zone with iron oxide along bedding planes and perpendicular fractures. Secondary calcite does not appear to be present. Zone may account for some C-4 lost recovery.	
40				Below 36.0' bedding angle increases to 65° - 70°. Healed fractures (white calcite filled) increase, up to 1/4" width, generally oriented perpendicular to bedding, often more prominent within limestone beds and typically dissipate or terminate within shale beds. By 41.0' bedding is approaching vertical. Healed (calcite filled) fractures oriented perpendicular to bedding are prominent within limestone beds. Local deformation, contorted bedding (small scale folds) are present. Below 41.5' beds may be slightly overturned.		The core bit/lifter was stuffed, indicating that the majority of lost C-4 recovery was most likely from the bottom of the run.	
41						Overdrilled corehole with 4 1/4" ID HSA.	
42	C-4	3.2' 64%	0%				
43				Below 42.3' some limestone beds are almost brecciated. At a minimum, highly deformed.			
44				Below 42.8' considerable white calcite filled fractures, highly deformed.			

BOREHOLE LOG V2 OAK RIDGE .GPJ CONTAINER CRAFT TEMPLATE WITH PID.GDT 4/4/18

Eagon & Associates, Inc.

EMDF Characterization Project Oak Ridge, TN	**BOREHOLE LOG**	Boring Number GW-988

Remarks:

Depth (feet)	Sample Method	Sample Recovery (feet or %)	Blows/6 in or RQD	SAMPLE DESCRIPTION	Graphic Log	Remarks	USCS
46	C-6	2.0' 100%	27.5%	Medium gray to medium dark gray (N5 - N4) to dark gray to grayish black (N3 - N2) INTERBEDDED LIMESTONE and SHALE. (Cont'd.) 46.2' Horizontal fracture (~1 inch thick) healed with calcite.		C-6: 44.6' - 46.6', 1559-1610. 44.6' - 46.6' Multiple hairline fractures healed with calcite.	
47	C-7	3.0' 85.7%	12.9%	Shale beds becoming dominant with depth. Contacts between shale and limestone are deformed, have a wavy appearance.		47.3' Fracture perpendicular to bedding plan healed with calcite.	
48						C-7: 46.6' - 50.1', 1620-1642.	
49						Driller noted no loss of water/circulation while drilling.	
50	C-8	1.5' 100%	0%	Below 50.0' shale and limestone content is approximately 50%. Rock is fresh, moderately to very intensely fractured. Fractures along bedding planes (45°) are mechanically induced. Multiple thin horizontal and vertical fractures that are healed with calcite. Shale has abundant slickensided surfaces along bedding planes.		C-8: 50.1' - 51.6', 1650-1710. 2/8/18 @ 1719 WL = 19.45 BGS. 2/9/18 @ 0835 DTW - 15.58 BGS.	
51							
52	C-9	4.0' 80%	36.4%	52.8' Fracture along bedding plane healed with calcite.			
53				53.2' - 53.4' Multiple hairline fractures perpendicular to bedding planes completely healed with calcite.			
54				Trace pyrite nodules and stringers within shale.		C-9: 51.6' - 56.6', 0933-1012.	
55				54.6' Fracture perpendicular to bedding plane healed with calcite.			
56				56.8' - 57.1' Shale and limestone are deformed with turbidation, approaching a brecciated appearance.			
57	C-10	5.0' 100%	17.2%	Below 57.0' bedding varies between 45° and 60°.		C-10: 56.6' - 61.6', 1029-1055.	
58							
59				59.0' - 59.1' Fracture perpendicular to bedding plane healed with calcite.			
60							
61				61.2' - 61.5' Hairline fractures perpendicular to bedding plane healed with calcite. 61.7' - 61.8' Fracture perpendicular to bedding plane healed with calcite.			
62	C-11	3.8' 76%	0%	From 62.2' - 62.3' fine glauconite nodules oriented along bedding plane. Only found in layers of limestone.		C-11: 61.6' - 66.6', 1108-1150. Driller noted pressure fluctuations while drilling.	
63							
64				63.6' - 63.8' Fine glauconite nodules oriented along bedding planes only within limestone. Pyrite nodules associated near glauconite grains/nodules. 63.9' - 64.1' Fracture perpendicular to bedding plane healed with calcite.			
65				64.4' - 64.7' Fracture perpendicular to bedding plane healed with calcite.			
66				Below 65.0' limestone beds are up to 3" thick. Slickensides present perpendicular to bedding plane in shale. Shale beds becoming dominant.		No loss of water/circulation during drilling.	
67	C-12	2.3' 92%	14.8%	66.6' - 67.0' Multiple fractures along bedding plane healed with calcite.		C-12: 66.6' - 69.1', 1358-1417. Driller noted rock feeding poorly. Pulled run.	
68				67.2' - 67.4' 1/4" thick fracture healed with calcite. Calcite is mostly white, some pink/orange in color.			
69				68.2' - 68.5' Multiple horizontal and vertical hairline fractures filled with calcite.			
	C-13	1.5' 100%	0%				

BOREHOLE LOG V2 OAK RIDGE.GPJ CONTAINER CRAFT TEMPLATE WITH PID.GDT 4/4/18

Eagon & Associates, Inc.

EMDF Characterization Project Oak Ridge, TN	**BOREHOLE LOG**	Boring Number GW-988

Remarks:

Depth (feet)	Sample Method	Sample Recovery (feet or %)	Blows/6 in or RQD	SAMPLE DESCRIPTION	Graphic Log	Remarks	USCS
71	C-13	1.5' 100%	0%	At 69.7' bedding turns near vertical with a fracture going from 69.9' to 72.3'. Fracture is healed with mudstone and calcite. Some limestone and shale rip-up clasts present within the mudstone. Highly deformed along bedding planes with some small-scale folds observed. Abundant horizontal fractures healed with calcite. Most breaks were probably mechanically induced. From 71.8' - 72.3' very intensely fractured zone. Healed with mudstone. Some healed with calcite. Below 72.3' bedding turns back to 40° to 50°.		C-13: 69.1' - 70.6', 1428-1444. C-14: 70.6' - 71.6', 1454-1504. C-15: 71.6' - 73.6', 1513-1531. Driller noted approximately 5% water loss in circulation. C-16: 73.6' - 75.0', 1542 - 1552. 2/9/18 at 1600 DTW = 6.79 BGS. 2/10/18 @ 0755, DTW = 4.88'.	
72	C-14	1.0' 100%	0%				
73	C-15	2.0' 100%	0%				
74	C-16	1.3' 92.9%	0%				
75							
76	NS						
77							
78							
79				Bottom of Borehole = 78.5'. Piezometer GW-988 installed in borehole. See Monitoring Well Installation Report GW-988 for details.		On 2/22/18 used T3W rotary rig to ream corehole and advance borehole to 78.5' using 5 7/8" tricone bit with air and water circulation. Finished drilling at 1120.	
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BOREHOLE LOG V2 OAK RIDGE.GPJ CONTAINER CRAFT TEMPLATE WITH PID.GDT 4/4/18

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